INTRODUCTION

Balance is the ability to maintain a position, to move voluntarily and to react to perturbation [1]. No single test has been reported as the gold standard in the assessment of balance or posture control [2]. However, series or battery of tests such as the one-leg stance [3-6], eyes open and eyes closed [5-7], and head turns [7] have been employed in previous studies. Other investigators have used more complex tests such as quantitative Romberg tests [8,9]. The cost, complexity, and size of the instrumentation required for these tests, however, make them impractical for general application [3].

In the clinical setting, balance is classified as either static or dynamic [1]. Maintenance of either static or dynamic balance requires that adequate afferent information from the visual, vestibular and proprioceptive systems are accurately sent to the brain [10,11]. Balance performance is an essential tool in the assessment and rehabilitation of patients with movement and stability dysfunctions. About 30% of persons with profound hearing impairment are estimated to have vestibular problems [12] and have been reported to perform poorly on vestibular function tests and balance skills [13-17]. This is because the vestibular end organs and cochlea are closely related anatomically and developmentally, therefore, strong potential exists for a related vestibular deficit when the hearing mechanism is impaired [18].

Consequent on the foregoing, some previous investigators have documented incidence of both vestibular and motor deficits in children with hearing impairments [13,14,18,19]; however, postural control and motor assessments are still not a routine procedure in hearing impaired children [20]. Furthermore, results on the relationship between motor function performance and vestibular end organs impairment is inconclusive. Some studies reported inferior balance and gross motor skills in children with hearing impairments compared with controls [13-17]. Conversely, comparable performances on motor co-ordination and vestibular tasks have been reported by some other studies [15,16,21]. The variability in the results of the previous studies can be implicated on methodological differences with respect to tests of vestibular function and motor performance, heterogeneity of samples and population differences. However, there seems to be a dearth of studies on vestibular function and motor performance in children with hearing impairment in Sub-Saharan Africa. This study compared static and dynamic balance...
performance of school children with hearing impairment and their age-and-sex-matched control.

**MATERIALS AND METHODS**

**Participants**

A total of 160 school children are comprising of 80 hearing impaired (49 boys and 31 girls) and 80 age and sex-matched control counterparts aged between 8 and 17 years participated in this study. The participants were recruited from Ibadan Home School for the Deaf, Ijokodo High School and Methodist Grammar School, Bodija, Ibadan, Nigeria. Criteria for participation among the hearing impaired, including giving assent using sign language were elicited by the school’s special education instructor as having stimulus intensity values of 30 dB or greater in audiometric screening, having no musculoskeletal and/or neurological disorders, and no involvement in any previous balance performance tests or active sport [22]. The criteria for participation among the control included giving verbal assent to participate in the study were being age and sex-matched of the hearing impaired participants, having no musculoskeletal and/or neurological disorders, and also no previous involvement in any balance performance tests or active sport.

**Procedure**

The Ethical Review Committee of the University of Ibadan/University College Hospital gave approval for this study. The permission of the matron of the Home School for the Deaf and the head teacher of the school for the participants in the control group were obtained respectively. The special education instructors assisted in explaining the study to the hearing impaired and to elicit assent. The test procedure was explained by one of the researchers to the participants in the control group, and each gave verbal assent to participate in this study.

In order to ensure a measure of consistency and reliability in data gathering the three principal investigators carried out three training and practiced sessions in order to enhance their proficiency at data gathering prior to the main study. During the study, the three principal investigators were randomly allocated roles to play in the assessment of the subjects. Each of the assessment tests was taken by different pairs of the investigators while the third investigator played a role of quality assurance and verification of adherence to methodology outline for the study. These roles were consistently reversed among the three principal investigators throughout the study period. The order of performance of the eyes opened, and eyes closed test was randomized, however, no blinding is involved in the study.

**Measurements**

The height and weight of the participants were measured following standardized procedures. Shoulder height was measured with reference from the acromion of the subject to the floor while the subject stood erect and was recorded in centimeters [23].

**One Leg Stance Test**

This test was used to assess static balance. This test was carried out on a level hard surface. A rectangular frame (50.8 cm × 45.7 cm) was placed on the floor, and each subject was instructed to place his/her dominant leg within the frame with hands by the sides. The contralateral leg was flexed at the knee with sole of the raised leg at the level of the knee of the stance leg. Timing with the stopwatch began when the subject assumed a stable position with the non-dominant leg raised and was stopped when the raised leg could no longer be maintained at the level of the contralateral lower limb; the raised leg touched the floor or the floor; loss of balance with the body displaced outside the wooden frame; use of arm or the dominant leg from bracing; or opening of the eyes during the eyes closed test. The order of performance of the eyes opened, and eyes closed test was randomized. Three trials were allowed for each of the test for all the participants and the best maximum time for each balance test was used for analysis. Participants were allowed between 3 and 5 min rest interval between each trial [5,6].

**Functional Reach Test (FRT)**

This test was used to assess dynamic balance. This measures the maximal forward reach over a fixed base of support of a subject [23]. The subject was asked to perform the FRT with the dominant arm. The dominant hand was determined by asking the subject that hand he/she uses when writing, eating or throwing the ball [24,25]. A transparent meter rule was mounted on the wall (parallel to the floor) with zero centimeter mark at the level of the participant’s acromion while subject stood with feet apart about shoulder width apart (distance between both acromia) in a comfortable symmetrical stance. The participant was then asked to make a fist and flex the shoulder at the glenohumeral joint such that it was parallel to the meter rule while avoiding projection, retraction and elevation of the shoulder.

The subject’s initial reach position was measured by noticing the point where the end of the third metacarpal was placed along the meter rule and was recorded in centimeters to one decimal place. For the end reach position, the subject was asked to reach forward as far as possible keeping the first parallel to the meter rule without losing balance. The subject was discouraged from touching the wall or meter rule, holding him/herself with the non-reaching hand or taking a step. The subject’s end reach position was then observed and recorded in centimeters to one decimal place. Three trials were done for the end reach position, and the average score of the three trials was determined. The initial reach score was subtracted from the final reach score, and the resulting score was used for data analysis [23].

**Statistical Analyses**

Data were summarized using both descriptives of mean and standard deviation. Inferential statistics involving independent t-test was used to compare static and dynamic balance between
both groups while Pearson’s product moment correlation was used to determine the relationship between static and dynamic balance. Alpha level was set at 0.05

RESULTS

The general characteristics of the hearing impaired and their control subjects are presented in Table 1. Table 2 shows a comparison of static and dynamic balance between the hearing impaired and their control subjects. Static balance eyes closed (SBEC), and static balance eyes opened (SBEO) was significantly lower among the hearing impaired than the normal hearing subjects. However, dynamic balance was higher among the hearing impaired but it was not statistically significant. Pearson’s product moment correlation analysis revealed no significant correlation between dynamic and static balance among the hearing impaired (FRT and SBEC, \(P = 0.175\); FRT and SBEO, \(P = 0.207\)) and normal hearing (FRT and SBEC, \(P = 0.126\); FRT and SBEO, \(P = 0.14\)) subjects, respectively. There was also no significant correlation between SBEC and SBEO among the hearing impaired (\(P = 0.645\)) and the normal hearing (\(P = 0.411\)) subjects, respectively.

DISCUSSION

This study compared static and dynamic balance performance in school children with hearing impairment and their normal-hearing counterparts. The result of this study indicate that static balance performance (both eyes closed and eyes opened) of the hearing impaired children were significantly lower than that of their normal hearing colleagues. This result is consistent with previous findings that persons with hearing impairments could also have balance deficits and performs poorly on vestibular function tests and balance skills [13-17]. There is replete of studies on static balance skills of persons with hearing impairments [13,14,26]. Most of these studies involved static balance performance testing using the one limb stance test [13,14,26-29]. Siegel et al. [13] noted that hearing deficits affect static balance skills negatively. Cushing et al. [30] observed large differences in the balance ability of children with sensorineural hearing loss requiring cochlear implantation compared with age-matched controls. Effgen [26] found that the hearing impaired showed subnormal performance on static balance test using a force platform. Potter and Silverman [14] investigated vestibular function and static balance skills in 34 deaf subjects and reported significant difference between their performances compared with a normative sample and found the normal subjects better. Similarly, Siegel et al. [13] reported that the scores of the hearing impaired subjects were lower than the normative values on the Bruininks-Oseretsky test of motor proficiency.

From the result of this study, no significant difference was observed in dynamic balance between the hearing impaired and normal hearing children. Contrary to this finding, Mann et al. [31] in a previous study compared static and dynamic balance in 28 subjects who had peripheral vestibular disorders and found subjects with lesser degree of the handicap performed better than their counterparts who were more affected. Other investigators also found the lower level of dynamic balance among children with hearing impairment compared with the controls [13,21,30-33]. Kegel et al. [27] submitted that children with hearing impairments have a higher risk for deficits in balance and gross motor skills compared with children who are developing typically.

From the result of this study, it was observed that the performance of dynamic balance does not depend on static balance. In consonance with this finding, Kegel et al. [27] reported that static and dynamic balance abilities could not be differentiated, and there seems not to be a valid dichotomy in children with hearing impairments. However, the finding of this study is at variance with the study by Mann et al. [31] who observed a moderate correlation between static and dynamic balance in patients with peripheral vestibular disease. Also from this study, a non-significant positive correlation was found between SBEO and eyes closed tests performance among the children with hearing impairment. This result is consistent with some previous reports [13,18,26,27]. Conversely, Potter and Silverman [14] who observed significant positive correlation between SBEO and SBEC tests. Jafari et al. [34] concluded that the development of static balance skills is longer than dynamic ones.

Table 1: Independent t-test comparison of general characteristics of hearing impaired and their control subjects (mean±SD)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Hearing impaired</th>
<th>Normal hearing</th>
<th>t-cal</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>11.95±2.72</td>
<td>11.94±2.73</td>
<td>0.31</td>
<td>0.744</td>
</tr>
<tr>
<td>Height</td>
<td>141.43±13.24</td>
<td>144.56±15.4</td>
<td>1.72</td>
<td>0.037</td>
</tr>
<tr>
<td>Weight</td>
<td>32.2±8.24</td>
<td>35.96±11.96</td>
<td>1.34</td>
<td>0.022</td>
</tr>
<tr>
<td>Shoulder height</td>
<td>116.31±11.97</td>
<td>119.92±13.7</td>
<td>1.53</td>
<td>0.078</td>
</tr>
</tbody>
</table>

Table 2: Independent t-test comparison of static and dynamic balance between hearing impaired and their control subjects

<table>
<thead>
<tr>
<th>Variables</th>
<th>Hearing impaired</th>
<th>Normal hearing</th>
<th>t-cal</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBEC</td>
<td>3.93±2.9</td>
<td>6.33±3.55</td>
<td>-4.618</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SBEO</td>
<td>22.1±14.92</td>
<td>33.35±11.89</td>
<td>-5.274</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>FRT</td>
<td>16.9±4.26</td>
<td>16±4.67</td>
<td>1.265</td>
<td>0.208</td>
</tr>
</tbody>
</table>


Physical therapists are often involved in the assessment, treatment and rehabilitation of children with various types of motor and neurological impairments. However, routine pediatric screening does not include an assessment of balance and motor deficits unless obvious neurological or orthopedic disorders are diagnosed [20]. Meanwhile, both the static and dynamic postural controls are very important and necessary to execute the movement [35,36]. Kegel et al. [27] submitted that the balance is a fundamental ability for the motor development of children; therefore, a valid and reliable assessment to identify weaknesses in balance is crucial. Furthermore, Jafari et al. [34] reported that children with severe to profound hearing-impaired showed more weakness than normal children in both static and dynamic balance abilities and recommends that functional tests of balance proficiency can help to identify balance disorders in these children [34]. Therefore, it is appropriate to compare
balance performance of hearing impaired with values of their age-matched counterparts with normal hearing.

A potential limitation of this study was the inability of the researcher to verify the nature of hearing impairment of the subjects because the authority of the home school for the deaf would not consent they be so examined. This study was conducted among school children, and the result should be interpreted with caution as it cannot be extrapolated to the adult population.

From the data obtained in this study, it is concluded that Children with hearing impairment perform poorly on static balance tests compared with their normal-hearing counterparts, while dynamic balance was comparable between both groups of subjects.

REFERENCES